

3.1.3. TOTAL OZONE OBSERVATIONS

Total ozone observations continued throughout 1993 at 15 of the 16 stations that comprise the U.S. Dobson spectrophotometer network (Table 3.6). Of the 15 stations, 5 were operated by CMDL personnel, 5 by NWS, 2 are domestic cooperative stations, and 3 are foreign cooperative stations.

Early in 1993, the instrument that was at the Poker Flat Research range was installed on the roof of the Geophysical Institute, University of Alaska, Fairbanks. This station is making both total ozone and Umkehr effect observations.

The Hauncayo, Peru, station ceased operation at the end of 1992 because of changes in the government structure in Peru. This was not reported to CMDL until after the end of 1993. The WMO is helping to restart the operations at another site in Peru to continue a long record of mea-

surements in a region of the world without many total ozone measurements.

Encoders and computers were added to the Dobson instruments at BRW; SMO; Bismarck, North Dakota; Caribou, Maine; Tallahassee, Florida; Nashville, Tennessee; Fresno, California; and Wallops Island. This change allowed for daily reporting of ozone from these stations to Boulder. The data were relayed to Aristotle University, Thessoloniki, Greece, where nearly real-time maps of total ozone for much of the northern hemisphere were prepared on behalf of the WMO in support of the Second European Stratospheric Arctic and Middle Latitude Experiment.

Provisional daily 1993 total ozone amounts applicable to local apparent noon for the stations listed in Table 3.6 were archived at the World Ozone Data Center (WODC), 4905 Dufferin Street, Ontario M3H 5T4, Canada, in *Ozone Data for the World*. Table 3.7 lists monthly mean total ozone amounts measured at the various stations.

TABLE 3.6. U.S. Dobson Ozone Spectrophotometer Station Network for 1993

Station	Period of Record	Instrument No.	Agency
Bismarck, North Dakota*	Jan. 1, 1963-present	33	NOAA
Caribou, Maine*	Jan. 1, 1963-present	34	NOAA
Wallops Is., Virginia*	July 1, 1967-present	38	NOAA; NASA
SMO*	Dec. 19, 1975-present	42	NOAA
Tallahassee, Florida*	May 2, 1964-Nov. 30, 1989; Nov. 1, 1992-present	58	NOAA; Florida State University
Boulder, Colorado*	Sept. 1, 1966-present	61	NOAA
Fairbankst, Alaska	March 6, 1984-present	63	NOAA; University of Alaska
Lauder, New Zealand	Jan. 29, 1987-present	72	NOAA; DSIR
MLO*	Jan. 2, 1964-present	76	NOAA
Nashville, Tennessee*	Jan. 2, 1963-present	79	NOAA
Perth, Australia	July 30, 1984-present	81	NOAA; Australian Bureau Meteorology
SPO	Nov. 17, 1961-present	82	NOAA
Haute Provence, France	Sept. 2, 1983-present	85	NOAA; CNRS
Huancayo, Peru	Feb. 14, 1964-Dec. 31, 1992	87	NOAA; IGP
BRW	June 6, 1986-present	91	NOAA
Fresno, California*	June 22, 1983-present	94	NOAA

*Stations for which total ozone data are tentatively reevaluated.

TABLE 3.7. Provisional 1993 Monthly Mean Total Ozone Amounts (m-atm-cm)

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Bismarck, North Dakota	316	329	334	346	331	321	320	302	300	272	299	351
Caribou, Maine	309	351	343	341	336	326	315	306	292	298	308	320
Wallops Is., Virginia	266	302	318	312	316	302	299	298	278	273	281	292
SMO	246	245	237	237	238	251	249	247	249	258	252	242
Tallahassee, Florida	-	-	277	291	310	297	301	301	281	267	269	281
Boulder, Colorado	282	296	299	311	303	318	293	286	278	274	279	313
Fairbanks, Alaska*	-	[353]	359	358	347	324	300	292	[275]	[329]	-	-
Lauder, New Zealand	287	268	265	284	290	326	308	347	329	353	330	292
MLO	225	234	249	265	275	262	257	257	256	254	250	243
Nashville, Tennessee	275	298	319	316	314	296	298	297	284	290	284	307
Perth, Australia	275	266	271	261	276	286	281	300	313	319	308	281
SPO	270	266	[278]	-	[269]	[255]	[271]	[270]	-	109	173	277
Haute Provence, France	282	300	319	330	320	320	320	[300]	297	301	290	284
Huancayo, Peru	Station closed											
BRW	-	-	359	377	360	321	285	297	268	260	-	-
Fresno, California	284	296	291	308	306	306	294	294	282	274	263	304

Monthly mean ozone values in square brackets are derived from observations made on fewer than 10 days per month.

*University of Alaska, Fairbanks

Reevaluation of NOAA total ozone data, some of which date back to the early 1960s, continued in 1993. The goal of this effort is to optimize data quality for "ground truth" validation of satellite ozone data, as well as for ozone trend analyses. The data base is comprised of nearly 400 station-years of data. By the end of 1993, data reevaluation was essentially completed for 12 of 25 stations, including those identified by asterisks in Table 3.6. Data for most of the remaining stations listed in the table will be reevaluated in 1994.

As illustrated in Figure 3.4, a tendency toward low ozone values was observed at Dobson stations over the contiguous United States toward the end of 1992 with the values becoming unprecedentedly low in 1993 [Komhyr *et al.*, 1994] (also Figure 3.5). The January through August 1993 ozone amounts were more than 2 standard deviations below normal 72% of the time and more than 3 standard deviations below normal 42% of the time. (Normal values were taken to be average monthly means derived from data obtained at the stations prior to 1982.)

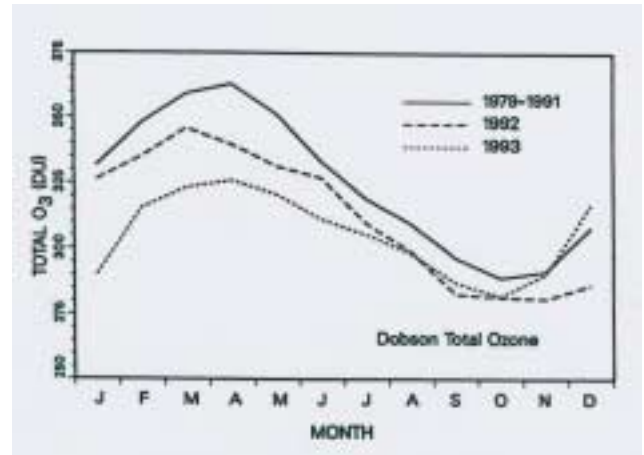


Fig. 3.4. Combined station total ozone monthly means from Bismarck, Caribou, Boulder, Wallops Island, and Nashville for 1992 and 1993 compared with averaged 1979-1991 ozone monthly means at these sites.

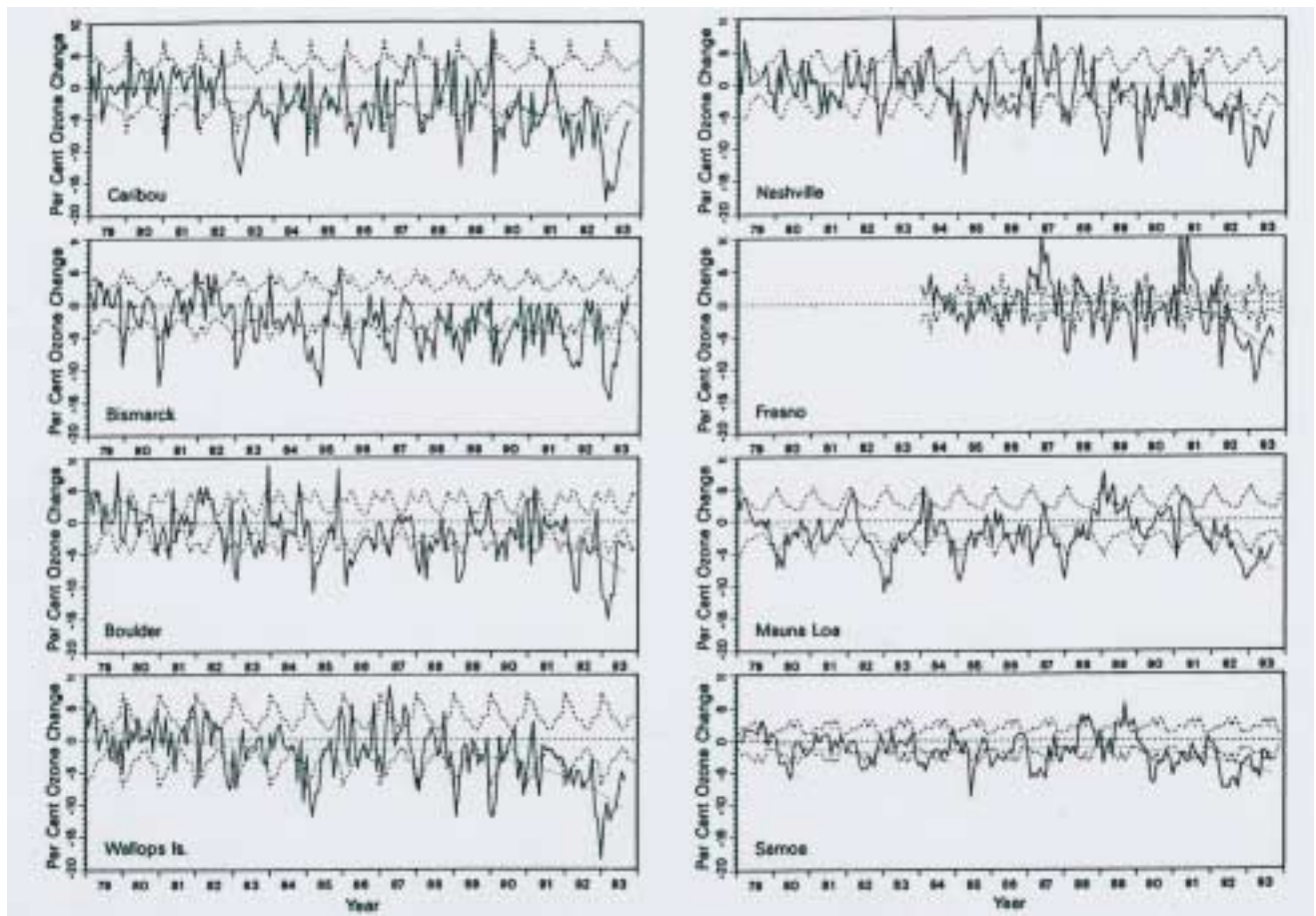


Fig. 3.5. January 1979-September 1993 percent decreases in monthly mean total ozone at six contiguous U.S. stations and in Hawaii and Samoa relative to long-term normal monthly means at the sites. Dashed lines are standard deviations of the normal monthly means expressed in percent. Dotted lines are the 4th degree polynomial fits to the solid line plots and represent the smoothed ozone trends at the stations.

The 1993 monthly mean ozone deviations from monthly normals are quantified in Table 3.8 for six U.S. mainland stations, MLO, and SMO. Fresno data, where observations began in 1983, were referenced to the 1960-1981 normal period from comparison of Boulder and Nashville data for the two time intervals. Note from the table that January-April 1993 ozone values were on average 12.6% below normal, with largest ozone deficits of 18% observed at Caribou and Wallops Island in January 1993. The record low ozone values persisted at four of the six U.S. mainland stations into summer. During May-August, ozone at these stations was on average 8.5% below normal. Ozone recovery toward normal values began in October and proceeded into 1994.

Comparison MLO data in Table 3.8 show a decrease with respect to the long-term normals of 5.5% during May-August 1993. At SMO lower ozone was observed in May-August of 1992 with values, on average, lower than long-term normals by 6.2%.

Figure 3.5 compares 1979-1993 monthly mean ozone data from the eight Dobson stations with long-term normal monthly means measured when atmospheric ozone destruction due to anthropogenic chlorofluoro-carbons was minimal. Dashed lines in Figure 3.5 represent standard deviations ($\pm 1\sigma$) of the normal monthly means. The solid lines plot changes in January 1979-September 1993 monthly mean total ozone amounts relative to monthly normals, expressed as a percentage. The dotted line in each plot is a smooth fourth-degree polynomial fit to the

solid line plot and represents the smoothed ozone trend for the station and the time interval under consideration.

Three features stand out in the dotted line plots of Figure 3.5. First, except for the short Fresno record, the remaining seven stations' data exhibit zero or near zero ozone trends at times of sunspot maxima (1979-1980 and 1988-1991) and the sunspot minimum (1985-1986). (At MLO and SMO the zero ozone trends corresponding to the 1985-1986 sunspot minimum are displaced toward 1982-1983, the time of the El Chichon volcanic eruption as well as the record 1982-1983 El Niño). Section, all stations show an overall downward trend in ozone with time, with the downward trends at MLO and SMO being the smallest. Third, all stations show a large increase in the downward ozone trend in 1992-1993.

Annual and seasonal ozone trends were computed, according to the method of *Bojkov et al.* [1990] from deseasonalized CMDL ozone data with solar cycle and equatorial QBO wind effects removed. Resulting trends presumably reflect ozone loss because of: (1) gas-phase photochemistry involving chlorine and bromine species; (2) heterogeneous chemical processes involving chlorofluorocarbons and polar stratospheric cloud and volcanic aerosols; (3) residual QBO effects not adequately accounted for in the model; and (4) dynamic effects induced by ENSO phenomena and stratospheric volcanic aerosols. The trend data for November 1978-September 1993 are compared in Table 3.9. Note (Table 3.9) that at five North American stations (Caribou, Bismarck,

TABLE 3.8. Percent Ozone Decreases at the CMDL Stations in 1993 Relative to Long-Term Normal Ozone Monthly Means

Station	Jan.	Feb.	March	April	Jan.-April O ₃ Decreases	May	June	July	Aug.	Sept.	May-Aug. O ₃ Decreases
Bismarck, North Dakota	-12.5	-13.4	-14.9	-8.9	-12.4	-9.7	-5.3	+0.5	-1.8	-1.7	-4.1
Caribou, Maine	-18.1	-14.7	-16.5	-15.9	-16.3	-12.7	-9.4	-7.8	-5.8	-5.2	-8.9
Boulder, Colorado	-11.5	-11.9	-15.1	-11.1	-12.4	-11.3	-3.2	-2.9	-3.9	-3.0	-5.3
Wallops Is., Virginia	-18.4	-13.1	-9.7	-12.7	-13.4	-9.9	-10.5	-7.7	-6.6	-6.4	-8.7
Fresno, California*	-8.1	-12.4	-16.4	-10.8	-11.9	-13.2	-7.9	-7.6	-5.8	-5.9	-8.6
Nashville, Tennessee	-13.3	-11.1	-6.6	-6.8	-9.5	-8.8	-10.2	-7.7	-4.9	-4.0	-7.9
MLO	-9.0	-7.7	-7.6	-6.9	-7.8	-4.4	-6.4	-6.2	-4.8	-3.8	-5.5
SMO	-2.7	-2.5	-5.1	-4.6	-3.7	-5.9	-1.4	-1.7	-2.9	-2.8	-3.0

*Values adjusted by -1.9 ± 1.4 (1σ) for reference to the mid-1960s to 1981 normal time interval.

TABLE 3.9. Trends for November 1978-August 1993

Station	Latitude	Annual		Dec.-Feb.		March-May		June-Aug.		Sept.-Nov.	
		Trend	Std. Error	Trend	Std. Error	Trend	Std. Error	Trend	Std. Error	Trend	Std. Error
Caribou, Maine	46.9°N	-4.49	0.86	-5.42	2.11	-6.51	1.28	-2.69	1.00	-2.62	1.57
Bismarck, North Dakota	46.8°N	-3.60	0.70	-3.79	1.63	-6.56	1.11	-2.02	1.14	-1.11	1.17
Boulder, Colorado	40.0°N	-3.50	0.71	-3.33	1.52	-7.21	1.43	-1.45	0.79	-0.92	1.20
Wallops Is., Virginia	37.9°N	-4.73	0.87	-7.03	1.66	-5.53	1.60	-3.99	1.14	-1.83	1.40
Nashville, Tennessee	36.3°N	-3.75	0.80	-5.87	1.50	-4.88	1.59	-3.18	1.02	-0.54	1.46
Fresno, California*	36.8°N	-3.45	2.15	-3.67	2.98	-3.96	3.94	-2.35	2.40	-3.81	2.35
MLO	19.5°N	-.048	0.94	-1.35	1.43	-0.12	1.73	-0.17	1.22	-0.33	0.90
SMO	14.3°S	-1.67	0.80	-0.97	1.16	-2.52	0.97	-1.41	1.38	-1.77	1.04
Average over first five stations		-4.01		-5.09		-6.14		-2.67		-1.40	

*Observations at Fresno began July 1983.

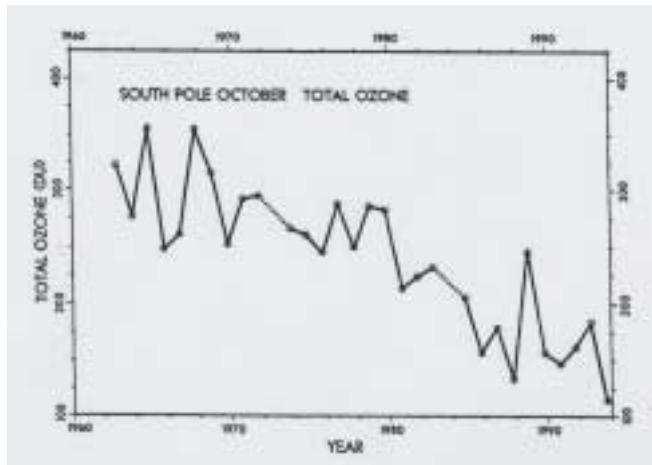


Fig. 3.6. SPO mean total ozone amounts for October 15-31 time intervals of 1962-1993.

Boulder, Wallops Island, and Nashville) having records for the 1978-1993 time interval under consideration, ozone decreased most quickly during spring months at an

average rate of -6% per decade. The ozone decrease rate was smallest at -1.4% per decade during autumn months. On an annual basis, the average ozone decrease rate at the five stations during November 1978-September 1993 was -4.0% per decade. With the addition of October 1993-December 1993 ozone data (not shown), the average annual seasonal downward ozone trends become smaller by about 1% per decade.

Record low ozone amounts were also observed at SPO during October and November of 1993. Mean monthly total ozone amounts measured during October 15-31 time intervals of 1962-1993 are plotted in Figure 3.6. (Dobson spectrophotometer total ozone observations first became possible at SPO in past years in mid-October following the polar night. With considerably less ozone at the Pole in Octobers of more recent years, fairly reliable data are obtained about a week earlier each year.) The October 1993 mean value of 117 DU was the lowest ever recorded at SPO. (The second lowest value of 134 DU was observed there in 1987.) Lowest ever ozone values were observed at SPO early in the month. The mean for October 9-14 was 91 DU, and the mean for October 15-18 was 100 DU.